Top-Mounted Propulsion Test Plans (TMP17)

James Bridges, Brenda Henderson, Dennis Huff
NASA GRC

Airport Noise/Commercial Supersonics Technology (CST) Project

Acoustics TWG

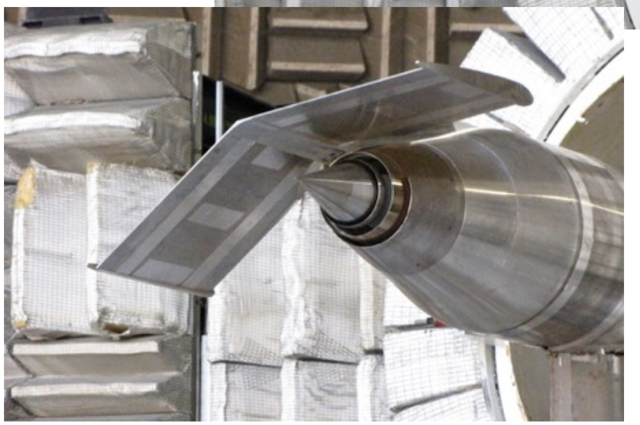
11 April 2017

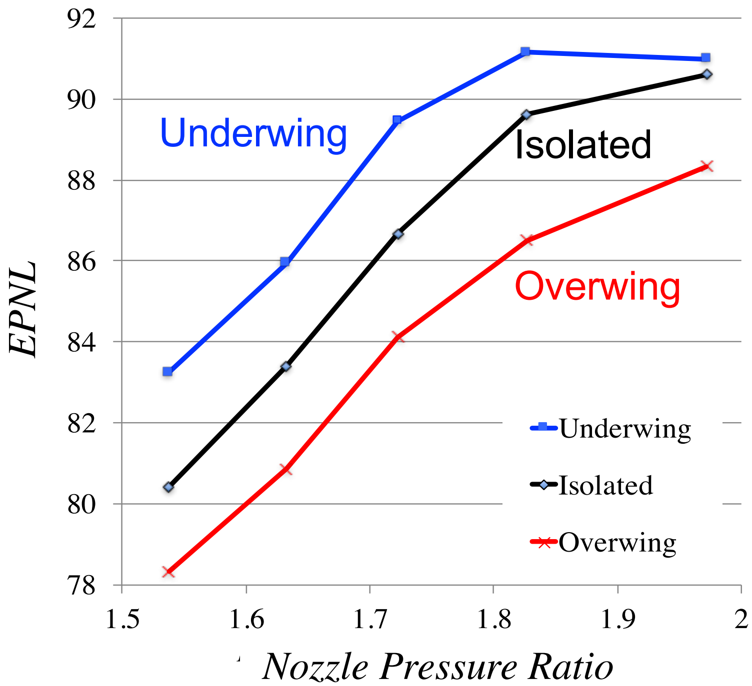
Summary of CST N+2 System Study and Validation Test

- CST Airport Noise goal: Chapter 4 –10EPNdB for a 70-100PAX M1.6 airliner.
- 2016 system study of **variable cycle engines** and **nozzle type**.
- Findings included:
  - Trading **specific thrust** for noise does not lead to economically viable design.
  - Nozzle-centric noise reduction concepts lose effectiveness at low cycles.
  - Uncertainties in predicting full-scale noise from model-scale data are too large.

JSI16 Test—Lessons and Strategies

- AAPL acoustic test of the LM1044 trijet in a modelscale test (JSI16)
  - Demonstrated validity of truncated planform representation in flight stream.
  - Established impacts of installation for trijet configuration, including IVP exhaust systems.
  - Showed again that installation biggest acoustic 'lever' available.

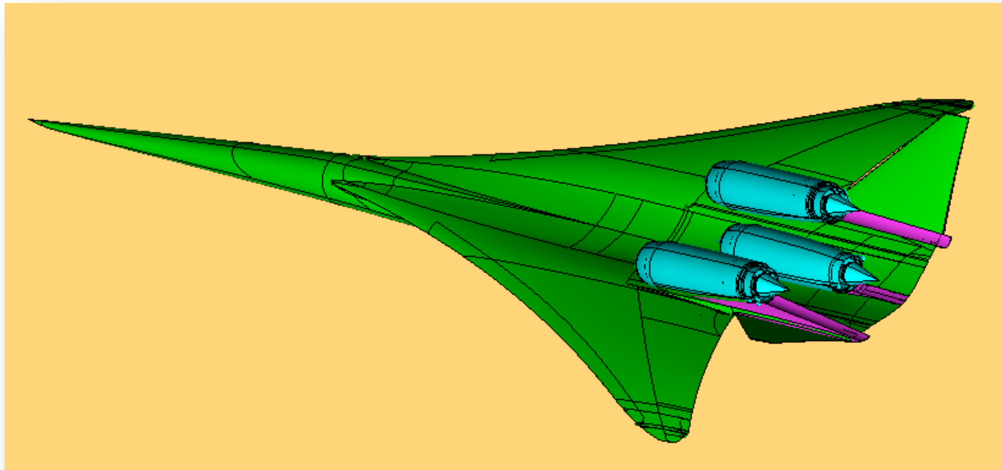


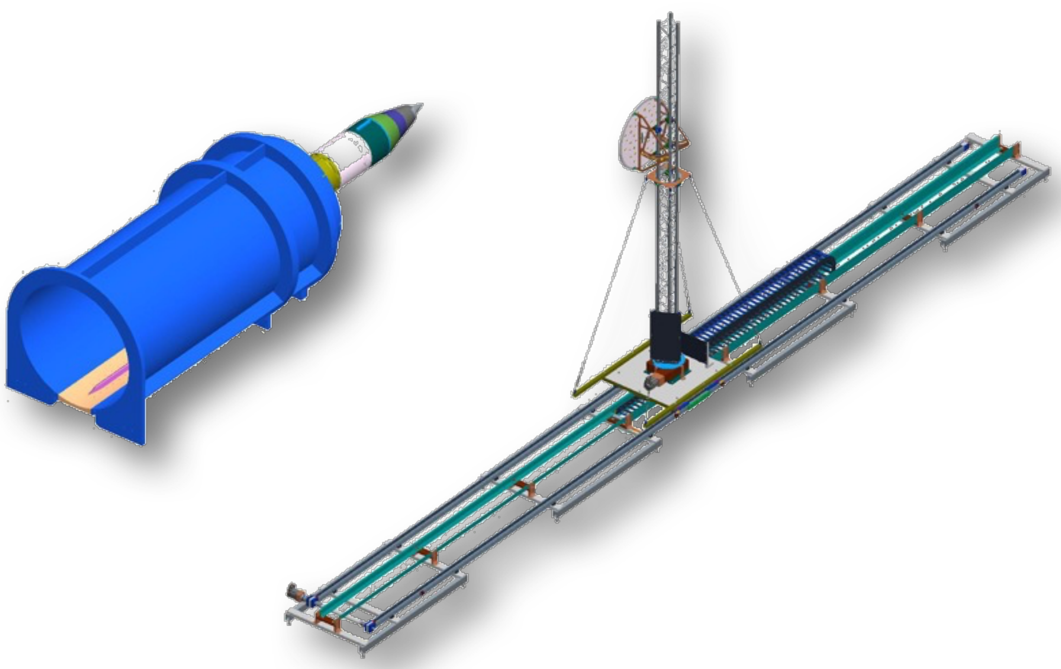


New Strategy: Top-Mounted Propulsion

TMP Demonstration

- In 2015-17 GE and NASA studied the noise benefits of having all propulsion on the topside of the vehicle.
  - **Significant,** mission-critical, **noise reduction**, both exhaust and fan, **could be achieved**.
  - NASA and GE separately developed **RANS-based prediction tools** to this non-standard propulsion installation.
- Predictions of 3-6 EPNdB reduction will be tested in model-scale test at AAPL, similar to the JSI16 test.
- New RANS-based methodology will be validated using new translating phased array.

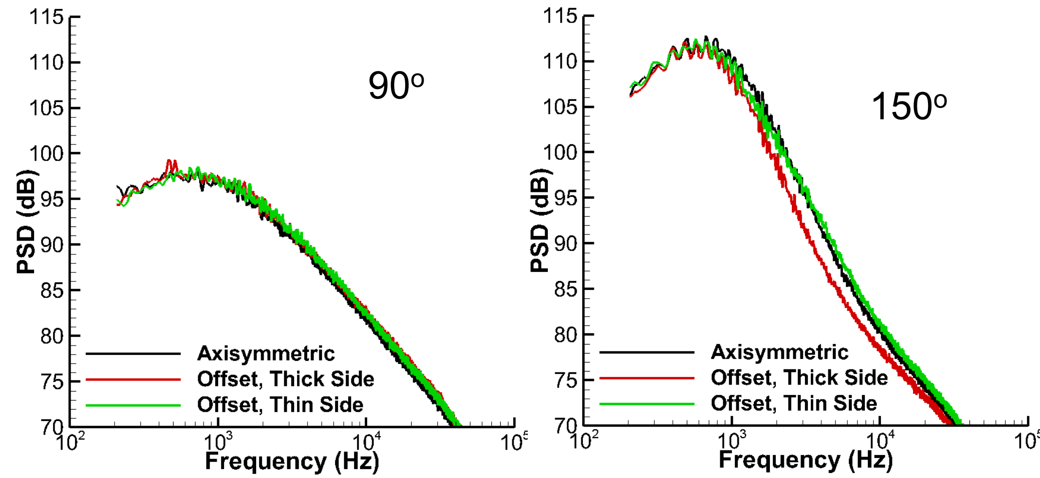


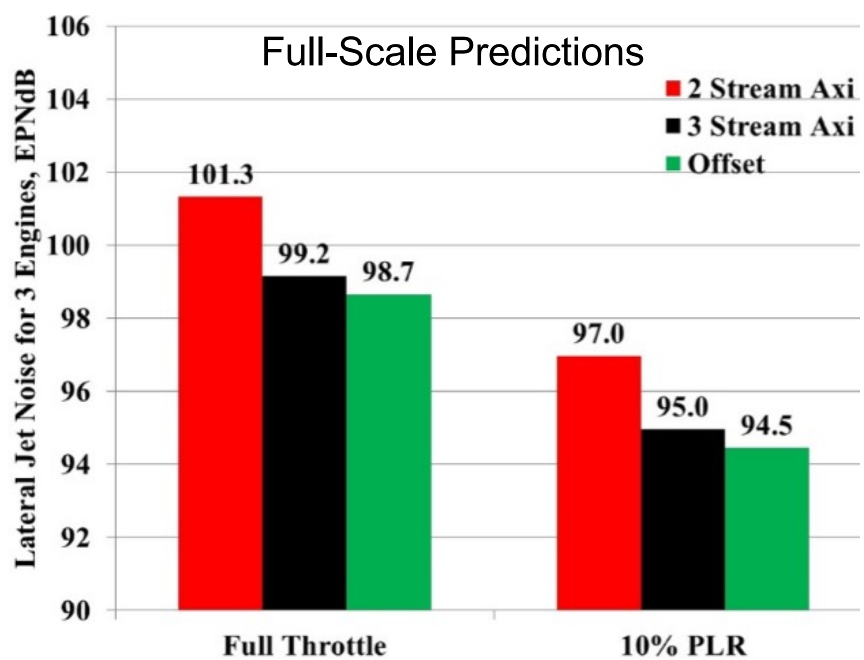


Offset Stream Experiments

- Objectives
  - Compare NASA TRPIV data with TRDGV data taken by VaTech
  - Compare convective speeds in axisymmetric and offset nozzles
  - Acquire data to improve predictive tools for offset streams
- Experiments
  - Time resolved PIV (TRPIV) for turbulent convection speeds
  - Hydrodynamic field pressure measurements for wave packet modeling
  - Far-field acoustics

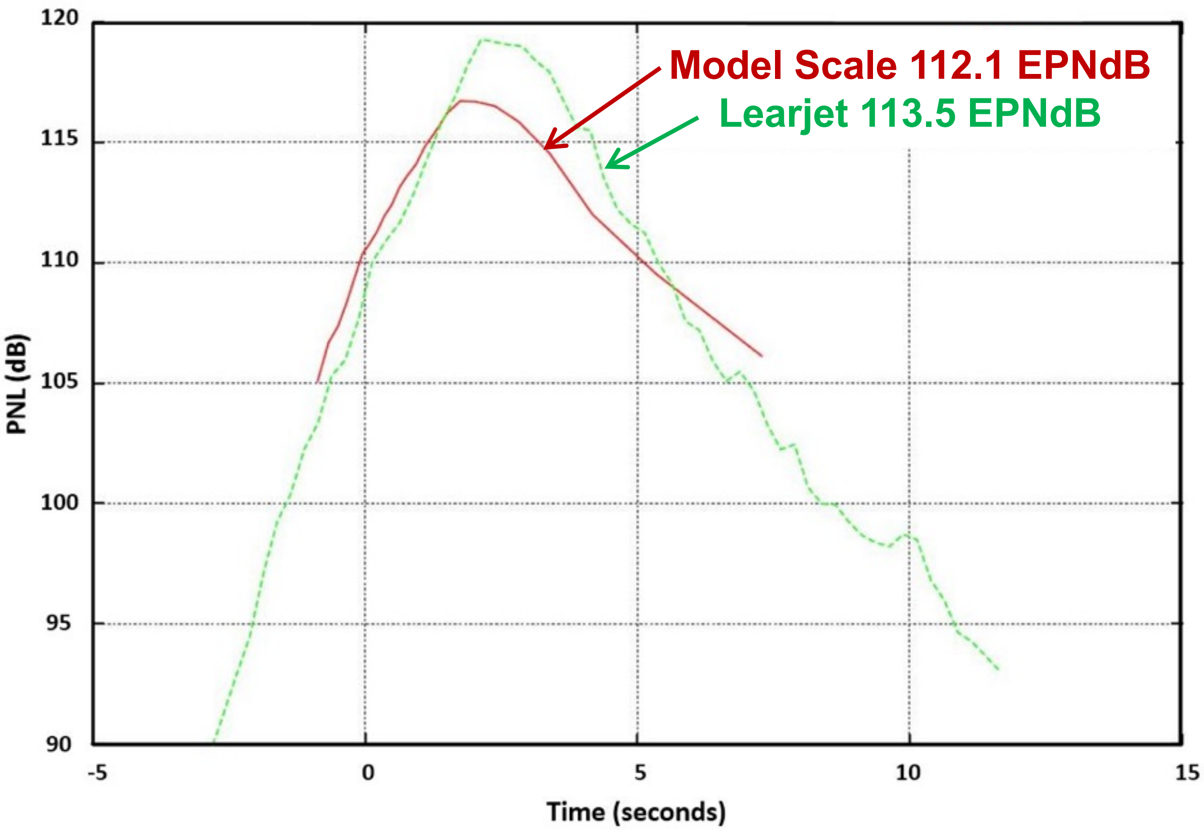
Model-Scale data for A_b/A_c = 1.5, A_t/A_c = 0.8





Flight and Model Tests of GE CJ610-6 Turbojet Nozzles

- Flight data with jet dominant source available from 2001 test using a NASA Lear25 aircraft. Model data was acquired before the flight test.
- Results showed discrepancies for PNL falloff rate and amplitudes.
- Acquire modelscale data with proper nozzle geometry to study differences between model and flight data.



New acoustic design tools to be validated

- Success of top-mounted propulsion depends upon ability to predict acoustic impacts of 3-D geometry and maximizing shielding benefit

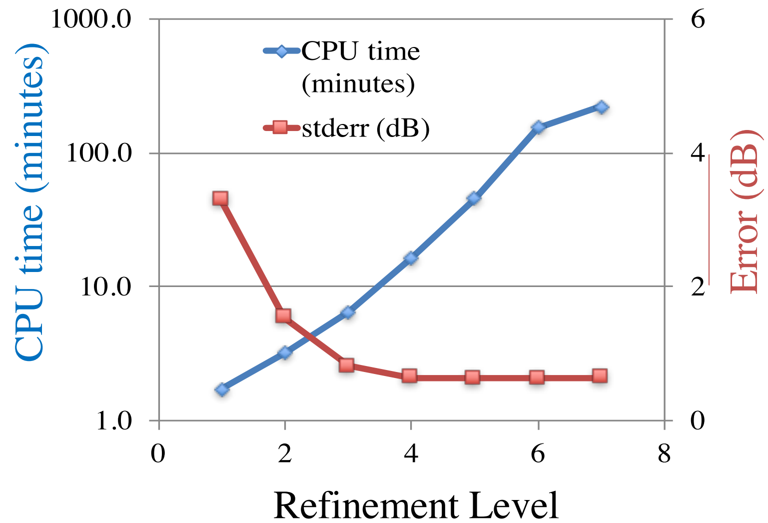
- Empirical (ANOPP, SAE)
  - Pro: Wide applicability in **axisymmetric** jets; $\pm$1dB; very fast—*O*(sec)
  - Con: Minimal geometry or shielding prediction capability

- RANS-based (NASA: JeNo, Leib; GE: GENO)
  - Pro: Captures impact of **nozzle features** on **mixing noise**—”trends”
  - Con: CFD woes (gridding!); numerics of Green’s function; slow—*O*(days)

- LES (Bailly. et al. Lyon, CharLES, CRAFT Tech, JENRE)
  - Pro: Demonstrated accurate for supersonic jets with geometric features
  - Con: Not robust for subsonic mixing noise? glacial—*O*(weeks)

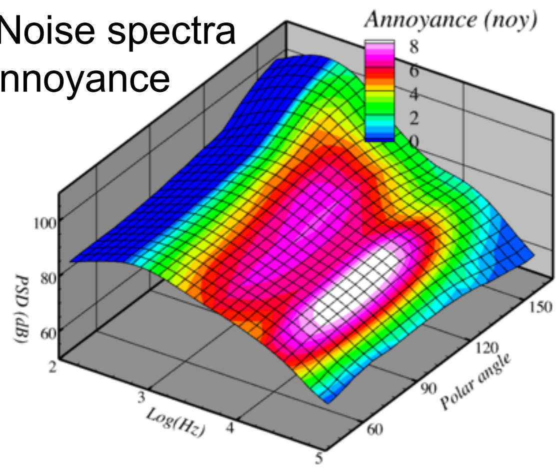
Simplified RANS-based prediction—Why

- Need fast, **quantitative** evaluation of geometric variations to guide design



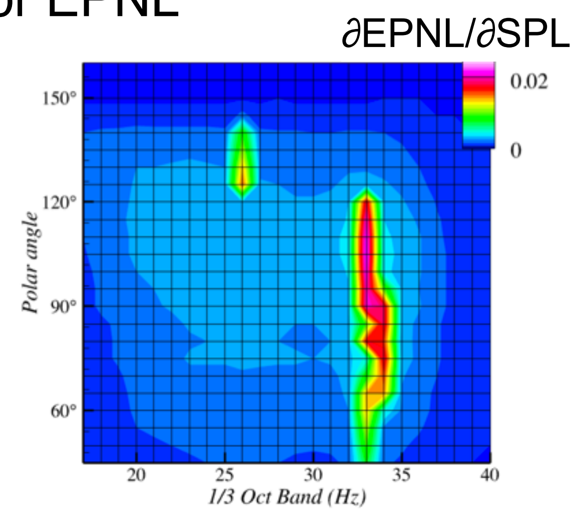
- Importance of high frequencies at broadside angles for EPNL

Shape: Noise spectra
Color: Annoyance



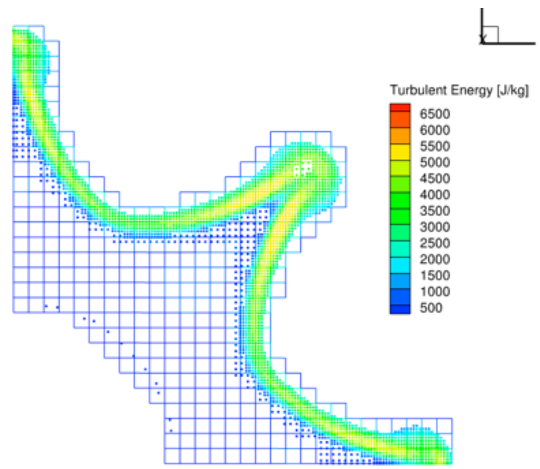
Human response drives what angles/frequencies need to be addressed to reduce EPNL.

Need to work high frequencies, broadside angles



Simplified RANS-based prediction—How

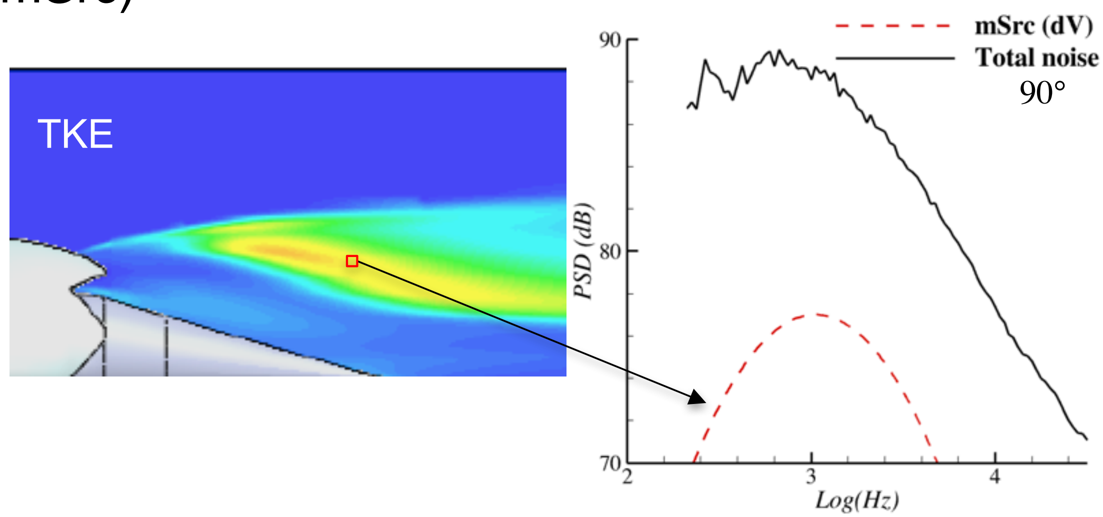
- Imbedded boundary CFD—no gridding, auto refinement, closely tied to CAD.
  - Structured vs unstructured
  - Lack of body-fitted grid – automatic gridding
  - Puts 'grid' where it needs to be!



- Turbulent mixing noise source (mSrc)

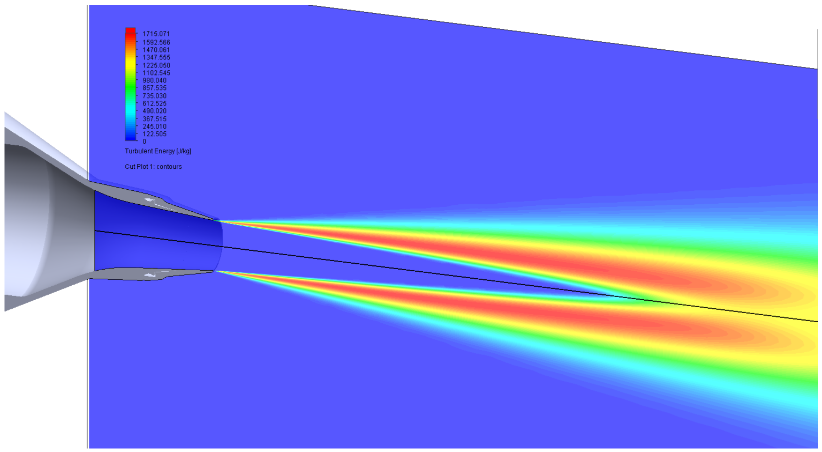
$$q(f) \propto \kappa^{7/2} \;\; 10^{A\left[\ln\left(B*\frac{\varepsilon/\kappa}{f}\right)\right]^2}$$

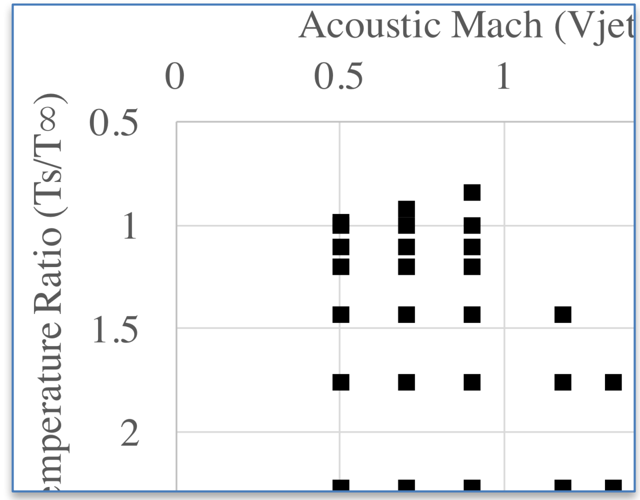
  - q is acoustic source density
  - κ is turbulent kinetic energy
  - ε is turbulent dissipation
  - No turbulent enthalpy term



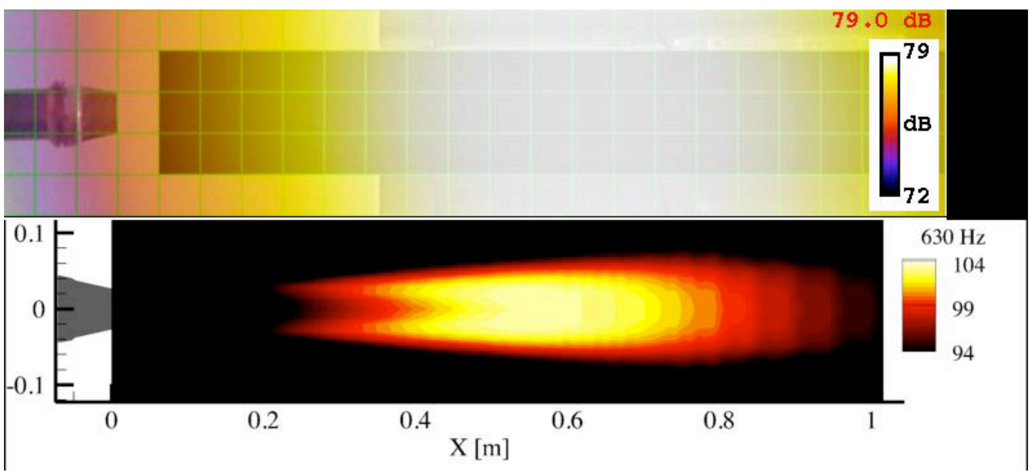
Demonstration of mSrc—Axisymmetric, single-flow

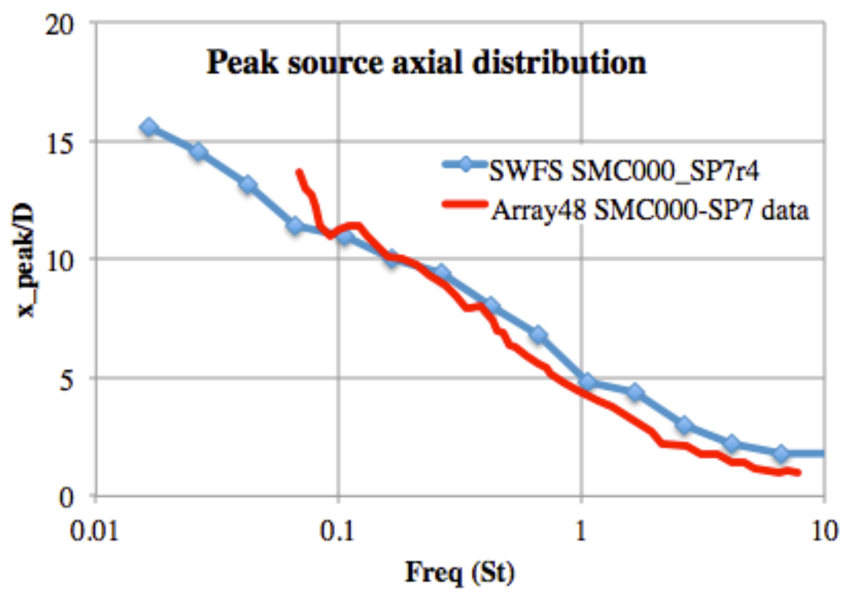
- SMC000 nozzle over Tanna matrix—Ma vs Ts @ 90˚





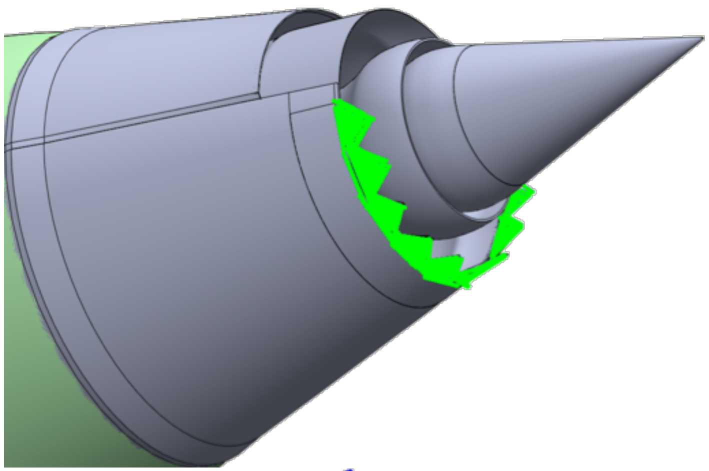
- Source distributions

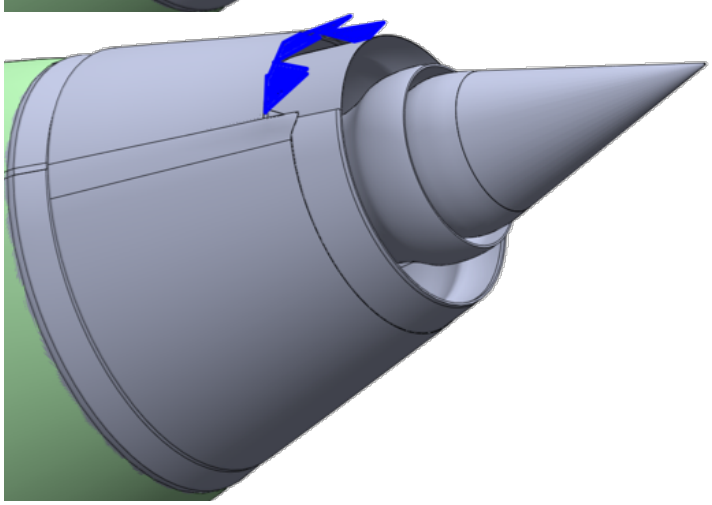


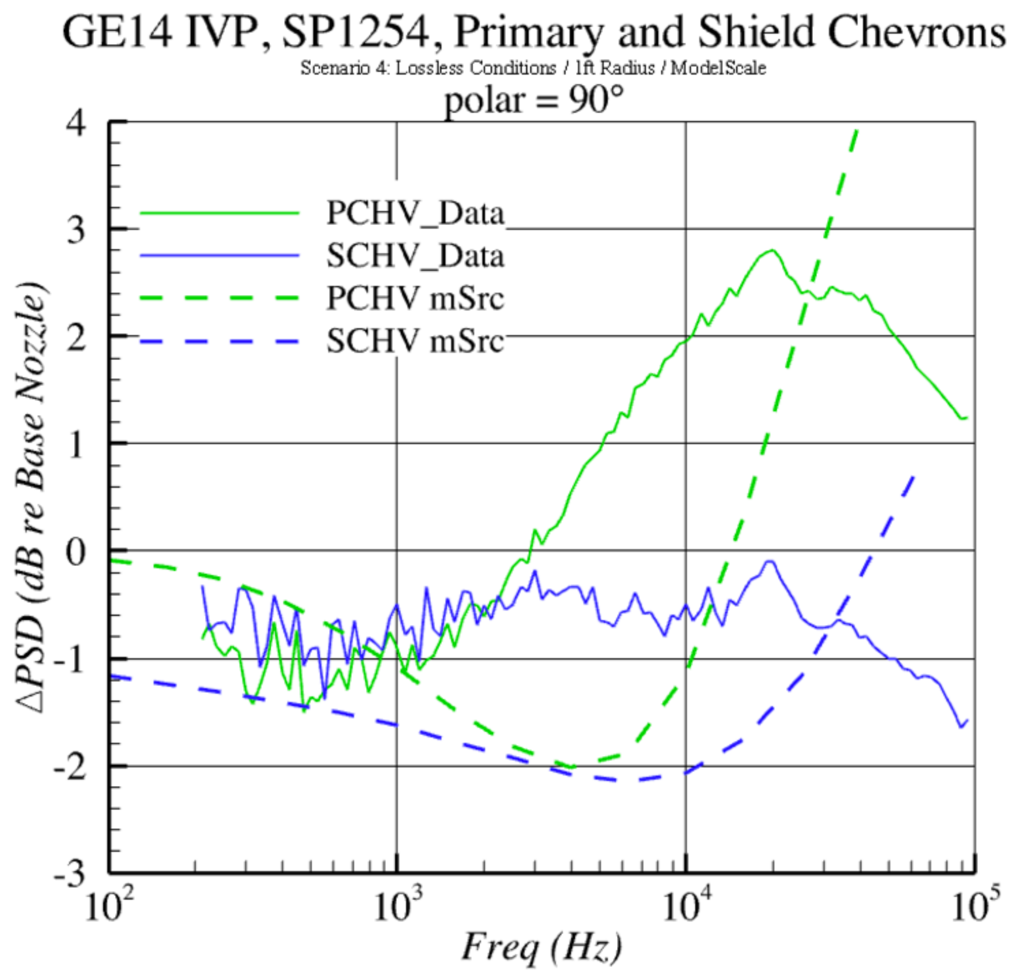


Demonstration of mSrc—Chevrons

- GE IVP+PCHV/SCHV (2014)



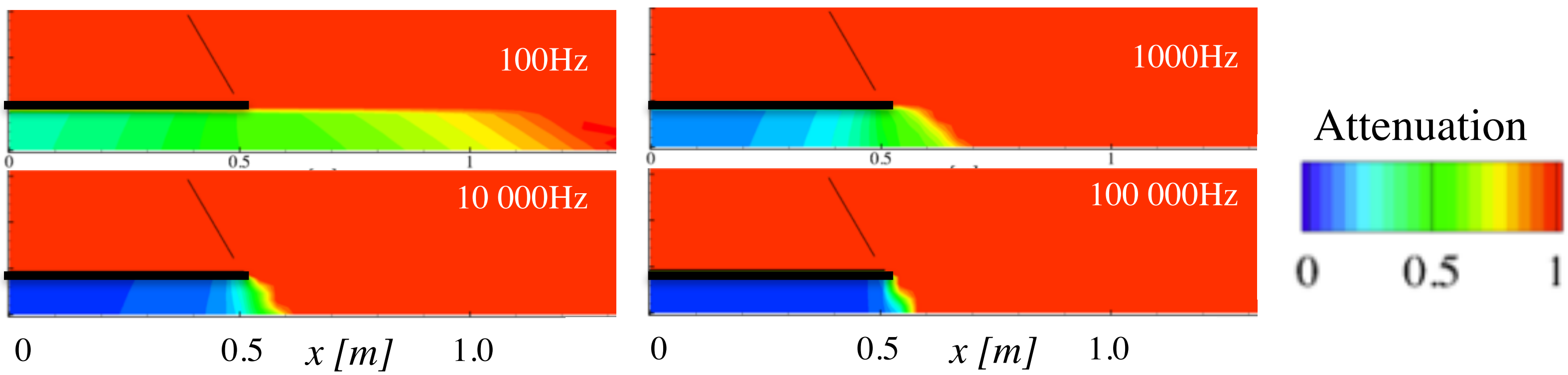




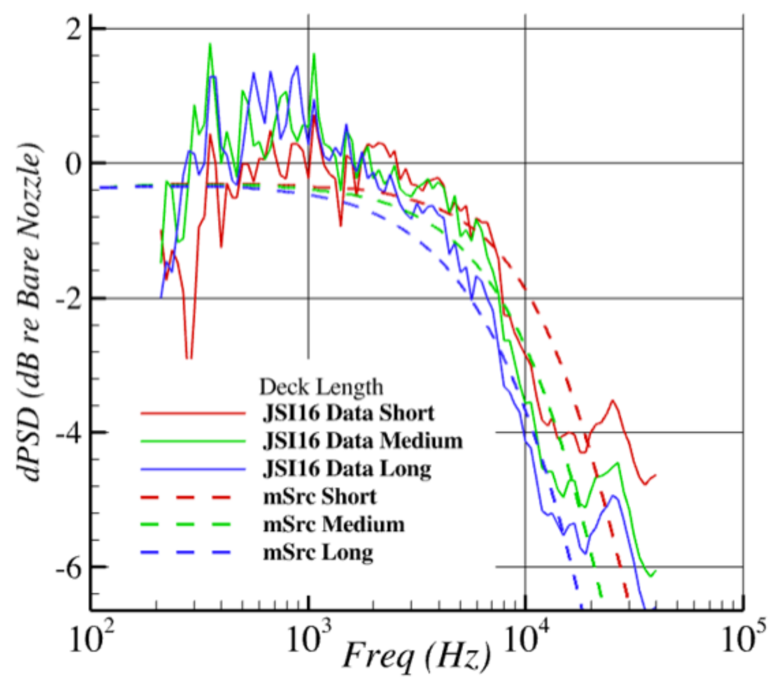
mSrc tends to underpredict high frequency penalty.

Demonstration of mSrc on Shielding

- No Green's Function
- Shielding based on Fresnel diffraction (Maekawa; ANOPP:WING)

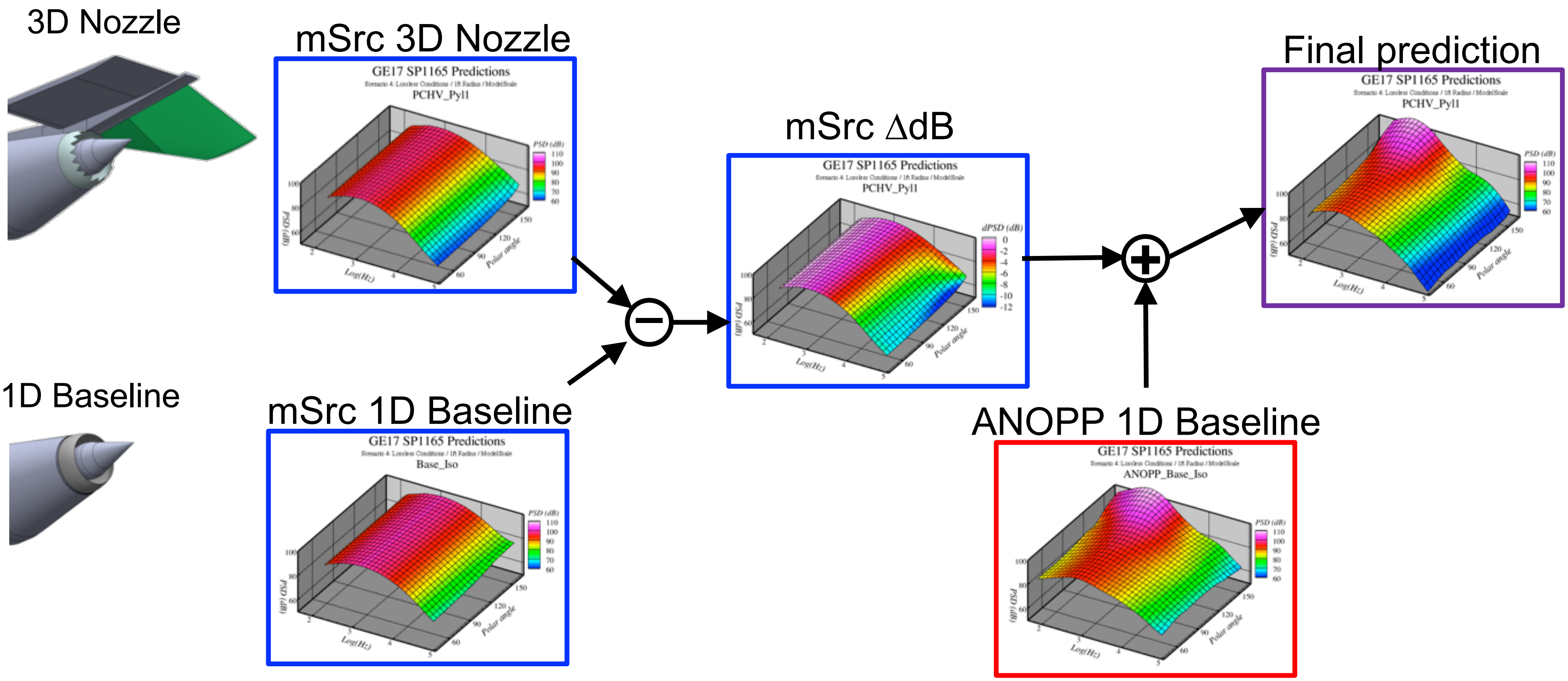


- JSI16 IV19 nozzle (center engine)



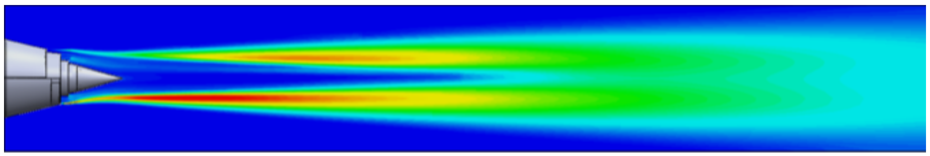
Simplified RANS-based prediction—How

- **Total prediction** by combining empirical PSD(freq, polar angle) and RANS-based geometry-dependent ΔdB from mSrc

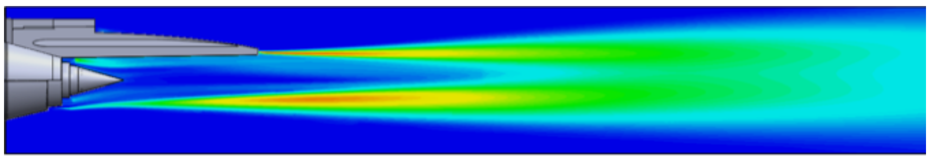


Optimized Chevron+Shielding Designs for TMP17

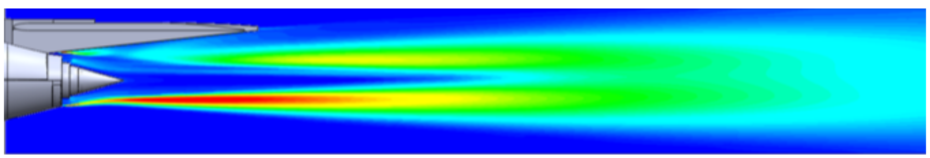
- Family of chevron treatments (location, penetration) on IVP nozzle studied with and without planforms for two installations (podded, embedded).



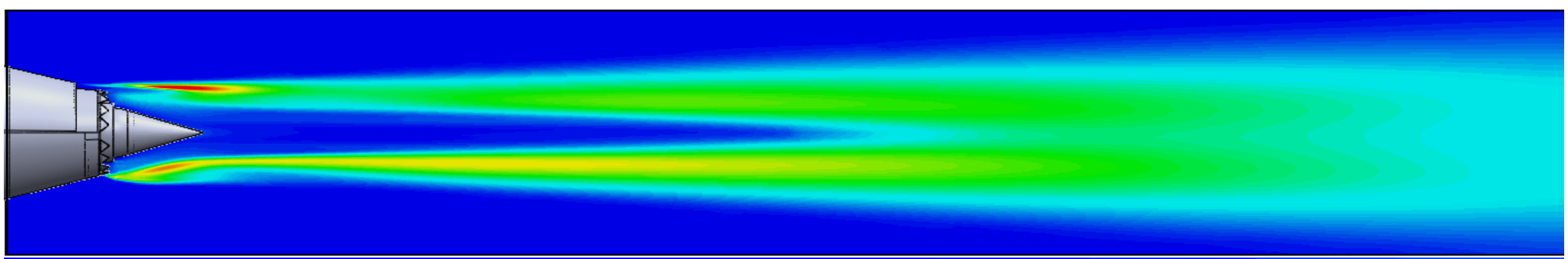
No chevrons, isolated



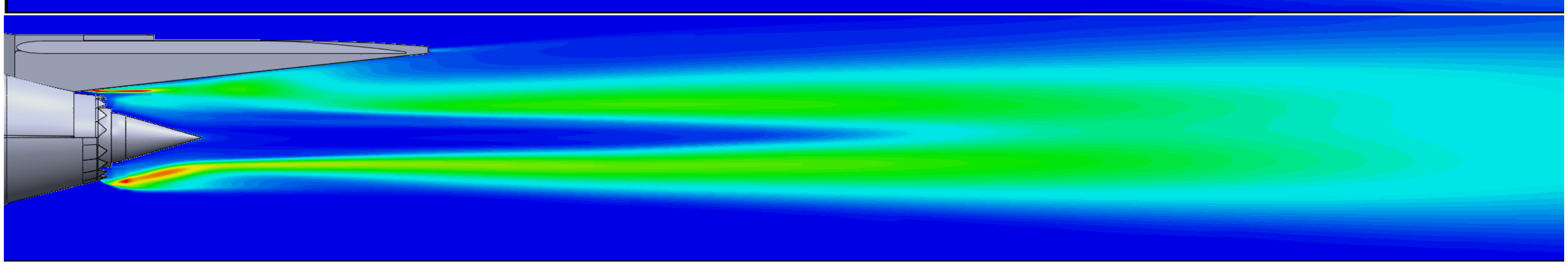
No chevrons, embedded



No chevrons, podded



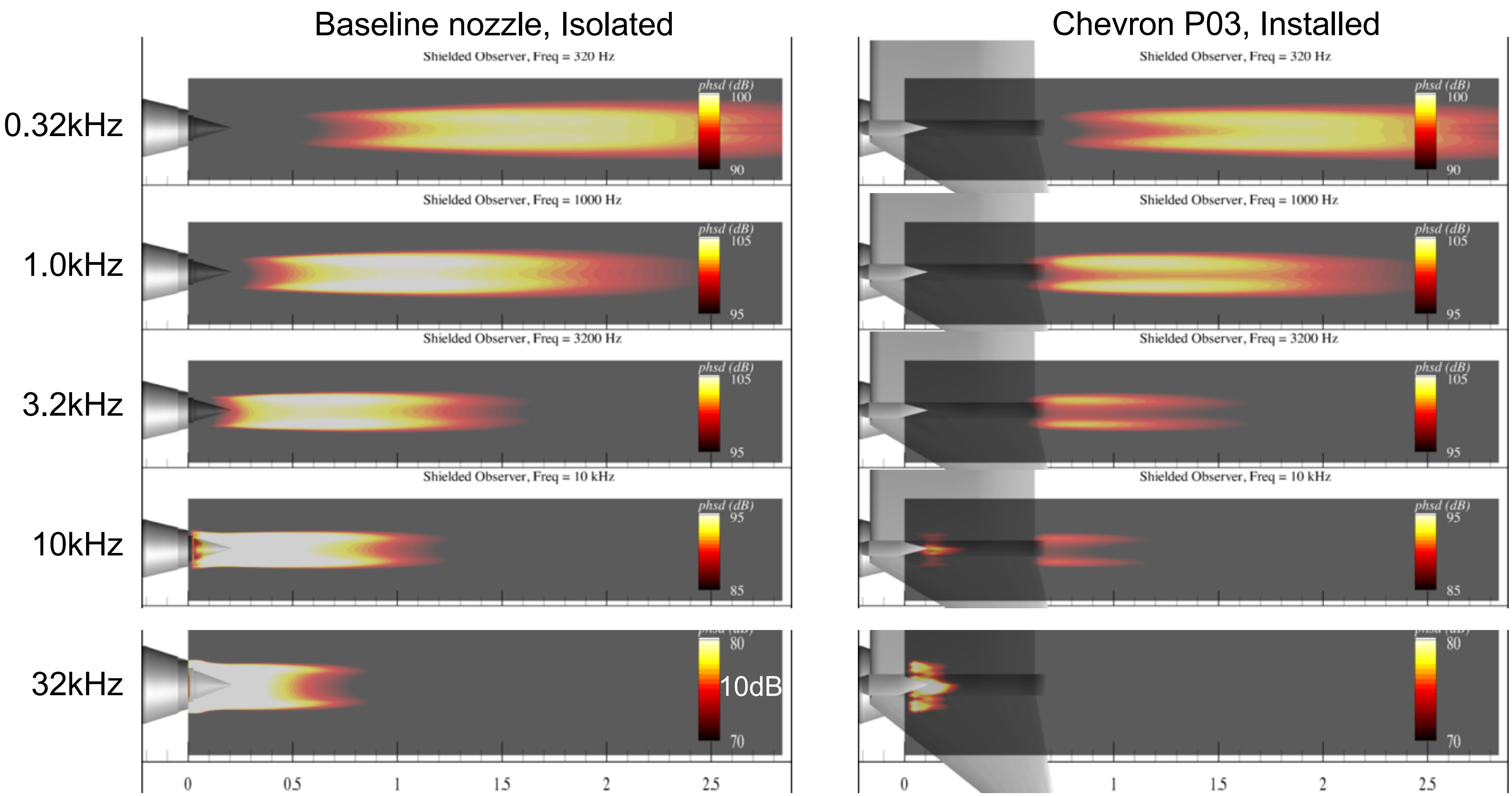
P24 chevrons, isolated



P24 chevrons, podded

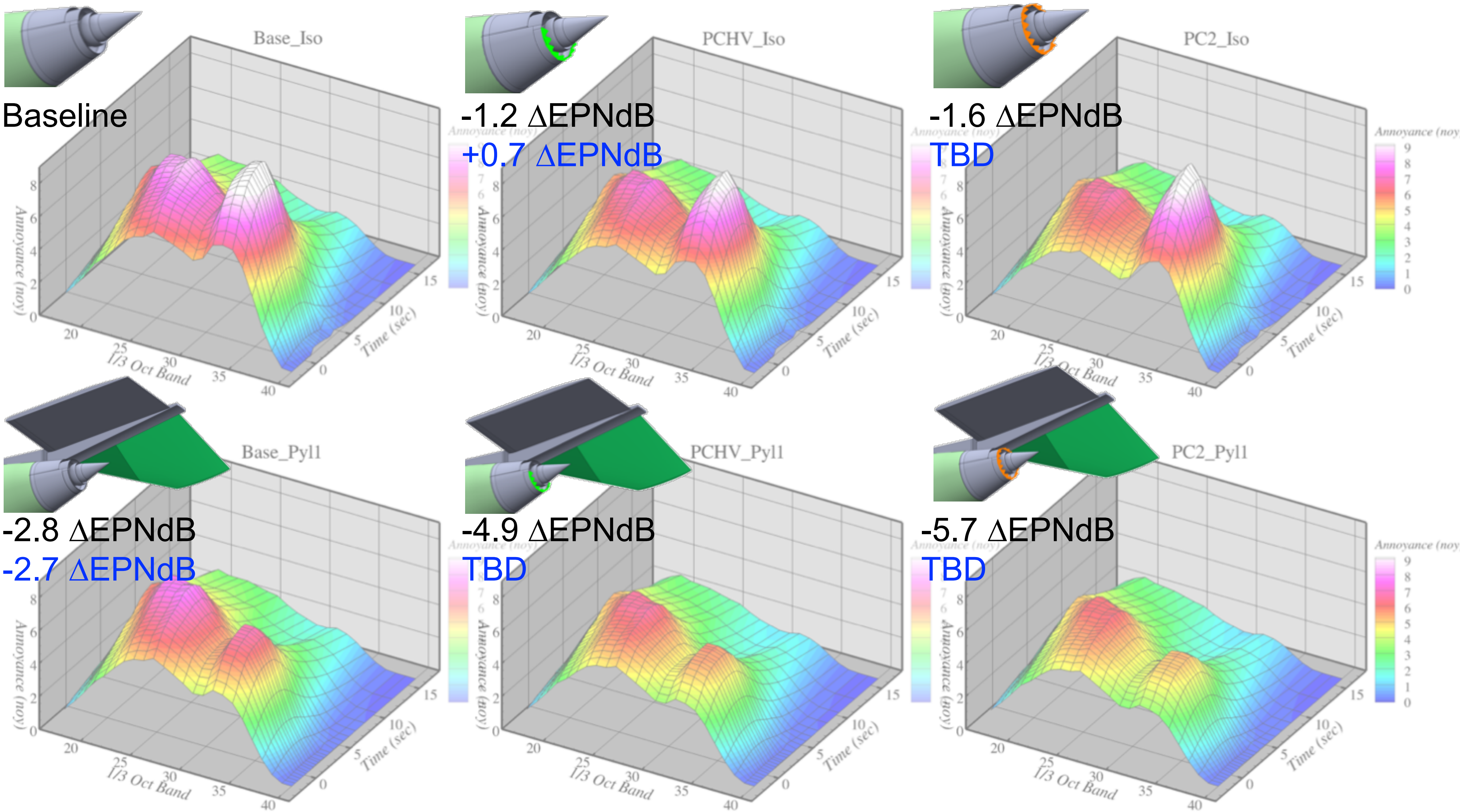
Expected source distributions for IVP: Baseline and Best

- Predicted source distributions for 90° ground observer
  - Phased array views (integrated through plume)
  - Integration of these over plane gives far-field noise



RANS-based Predictions of Top-Mounted IVP Nozzles

- Comparison with existing data and projected benefits of new concepts



Summary

- System studies show that propulsion noise remains a challenge for larger commercial supersonic aircraft.
  - Many noise reduction strategies do not have enough benefit at the low specific thrust required to be noise-compliant
  - LTO operations taking advantage of supersonic aircraft characteristics help noise.
  - Relationship between model- and full-scale becomes important when speaking of absolute certification levels.
  - Top-mounted propulsion, combined with modified plume, gives new promise for quiet aircraft
- Tools for optimizing top-mounted propulsion are critical
  - Accounting for nozzle geometry, shielding required.
  - Engineering solutions may be found by focusing on metric-critical noise sources
- Next tests will validate TMP strategy, anchor databases to real aircraft, and improve prediction tools for aft-directed propulsion noise